Hierarchical Phased Array Antenna Focal Plane for Cosmic Microwave Background Polarization and Sub-mm Observations

Completed Technology Project (2017 - 2021)

Project Introduction

We propose to develop planar-antenna-coupled superconducting bolometer arrays for observations at sub-millimeter to millimeter wavelengths. Our pixel architecture features a dual-polarization, log-periodic antenna with a 5:1 bandwidth ratio, followed by a filter bank that divides the total bandwidth into several broad photometric bands. We propose to develop an hierarchical phased array of our basic pixel type that gives optimal mapping speed (sensitivity) over a much broader range of frequencies. The advantage of this combination of an intrinsically broadband pixel with hierarchical phase arraying include a combination of greatly reduced focal-plane mass, higher array sensitivity, and a larger number of spectral bands compared to focal-plane designs using conventional single-color pixels. These advantages have the potential to greatly reduce cost and/or increase performance of NASA missions in the sub-millimeter to millimeter bands. For CMB polarization, a wide frequency range of about 30 to 400 GHz is required to subtract galactic foregrounds. As an example, the multichroic architecture we propose could reduce the focal plane mass of the EPIC-IM CMB polarization mission study concept by a factor of 4, with great savings in required cryocooler performance and therefore cost. We have demonstrated the lens-coupled antenna concept in the POLARBEAR ground-based CMB polarization experiment which is now operating in Chile. That experiment uses a single-band planar antenna that gives excellent beam properties and optical efficiency. POLARBEAR recently succeeded in detecting gravitational lensing B-modes in the CMB polarization. In the laboratory, we have measured two octaves of total bandwidth in the log-periodic sinuous antenna. We have built filter banks of 2, 3, and 7 bands with 4, 6, and 14 bolometers per pixel for two linear polarizations. Pixels of this type are slated to be deployed on the ground in POLARBEAR and SPT-3G and proposed to be used on a balloon by EBEX-IDS and in space on the LiteBIRD CMB polarization mission. The deliverables for the proposed work include: *Fabrication and test of a sinuous-antenna-based pixel with a 5:1 total bandwidth. Separate pixels will be built that are sensitive down to 30 GHz and others that are sensitive up to 400 GHz to cover the full range required for CMB measurements and to push into the sub-mm wavelength range. The efficiency of these pixels will be maximized by introducing a low loss silicon nitride insulator layer in all of the transmission lines. *Hierarchical phased arrays that use up to five levels of arraying will be fabricated and tested. The hierarchical phased array approaches the optimal mapping speed (sensitivity) at all frequencies by adjusting the beam size of the array with frequency. *We will develop 3 and 5 layer anti-reflection coatings using a new ``thermal spray" technique that we have developed which heats ceramics and plastics to melting temperature an then sprays them on optical surfaces with excellent uniformity and thickness control. The dielectric constant of each layer can be adjusted by choosing mixing ratios of high and low dielectric constant materials. Prioritization committees including the Astro2010 decadal, Quarks to Cosmos, and Weiss Committee have strongly advocated for prioritizing Cosmic Microwave Background polarization

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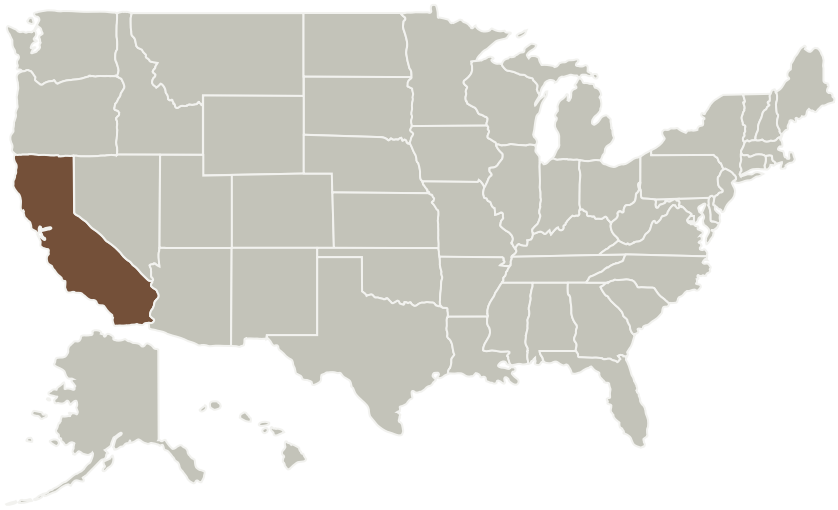
measurements and other science goals in the mm and sub-mm wavelength regime. The technology we propose to develop has the potential to greatly increase the cost effectiveness of potential missions in this frequency range. We have assembled an experienced team that includes expertise in antenna design, RF superconducting circuits, microfabrication, and CMB observations. Our team includes detector and/or CMB observation experts Bill Holzapfel, Adrian Lee, Akito Kusaka, and Aritoki Suzuki.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Regents of the University of California	Lead Organization	Academia	Oakland, California

Primary U.S. Work Locations
California

Organizational Responsibility

Responsible Mission Directorate:

Science Mission Directorate (SMD)

Lead Organization:

Regents of the University of California

Responsible Program:

Astrophysics Research and Analysis

Project Management

Program Director:

Michael A Garcia

Program Manager:

Dominic J Benford

Principal Investigator:

Adrian T Lee

Co-Investigators:

Akito Kusaka
Aritoki Suzuki
David M Weldon
William L Holzapfel

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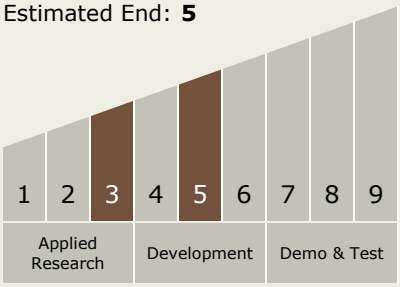
Technology Maturity (TRL)

Start: **3**
Estimated End: **5**



Technology Areas

Primary:

- TX08 Sensors and Instruments
  - TX08.1 Remote Sensing Instruments/Sensors
    - TX08.1.1 Detectors and Focal Planes

Target Destination

Outside the Solar System